CHEST

Original Research

PULMONARY VASCULAR DISEASE

A Validated Risk Model to Predict 90-Day VTE Events in Postsurgical Patients

Christopher J. Pannucci, MD; Sandra Laird, MHA, RN; Justin B. Dimick, MD; Darrell A. Campbell, MD; and Peter K. Henke, MD

Background: **VTE is the proximate cause of 100,000 deaths in the United States each year. Perioperative VTE risk among surgical patients varies by 20-fold, which highlights the importance of risk stratification to identify high-risk patients, in whom chemoprophylaxis can decrease VTE risk, and low-risk patients, for whom the risk-benefit relationship of prophylaxis may be unfavorable.**
Methods: **We used data from a statewide surgical quality collaborative for surgical procedures performed between 2010 and 2012. Regression-based techniques identified predictors of 90-day VTE while adjusting for procedural complexity and comorbid conditions. A weighted risk index was created and was validated subsequently in a separate, independent dataset.**
Results: **Data were available for 10,344 patients, who were allocated randomly to a derivation or validation cohort. The 90-day VTE rate was 1.4%; 66.2% of the derivation cohort and 65.5% of the validation cohort received chemoprophylaxis. Seven risk factors were incorporated into a weighted risk index: personal history of VTE, current cancer, sepsis/septic shock/systemic inflammatory response syndrome, age ≥ 60 years, BMI ≥ 40 kg/m², male sex, and family history of VTE. Prediction for 90-day VTE was similar in the derivation and validation cohorts (areas under the receiver operator curve, 0.72 and 0.70, respectively). An 18-fold variation in 90-day VTE rate was identified.**
Conclusions: **A weighted risk index quantifies 90-day VTE risk among surgical patients and identifies an 18-fold variation in VTE risk among the overall surgical population.**

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Abbreviations: ACCP = American College of Chest Physicians; AUROC = area under the receiver operator curve; CPT = Current Procedural Terminology; CVC = central venous catheter; MSQC = Michigan Surgical Quality Collaborative; PE = pulmonary embolus; SIRS = systemic inflammatory response syndrome

Annually, 12 million hospitalized patients are at risk of VTE, which includes DVT and pulmonary embolus (PE).[1,2] Nearly 600,000 adults are given a diagnosis of VTE each year, and PE is responsible for > 100,000 deaths annually in the United States.[3-5] This staggering number of PE-associated deaths is higher than the annual mortality from breast cancer and motor vehicle accidents combined.[6,7]

Patients with VTE have unacceptably high short-term mortality and long-term morbidity, which makes prevention of VTE paramount. Prevention begins with an understanding of a patient's risk. Studies have shown that a 10- to 20-fold difference in VTE risk exists among the overall surgical population.[8-11] The American College of Chest Physicians (ACCP) guidelines on VTE prevention have long been the standard for conceptualizing VTE risk.[12] The most recent ACCP guidelines, Antithrombotic Therapy and Prevention

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Affiliations: From the Section of Plastic Surgery (Dr Pannucci), the Division of Minimally Invasive Surgery (Dr Dimick), and the Section of Vascular Surgery (Dr Henke), University of Michigan Hospitals (Dr Campbell); and Michigan Surgical Quality Collaborative (Ms Laird), Ann Arbor, MI.
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Correspondence to: Peter K. Henke, MD, Section of Vascular Surgery, Cardiovascular Center, Room 5463, University of Michigan, 1500 E Medical Center Dr, Ann Arbor, MI 48109-5867; e-mail: henke@med.umich.edu

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of Thrombosis, 9th ed: ACCP Evidence-Based Clinical Practice Guidelines, acknowledge the importance of individualized risk stratification.[12] However, the guidelines note that the available models lack rigorous statistical development, extensive validation or both in large, independent patient populations. The labor-intensive nature of the existing models, which require yes/no answers to between 18 and 40 questions, makes accurate and reliable completion by physicians unlikely.[12-15] Among the existing risk models that have been developed rigorously from large databases,[8,15] none was able to incorporate VTE-centric risk factors such as a personal or family history of VTE, central venous catheter (CVC), or thrombophilia. The existing risk models were also developed to predict 30-day VTE risk, although studies have shown that the postoperative risk of VTE may extend to 90 days after surgery.[16]

In this study, we used prospective data from a statewide clinical registry that includes VTE-specific risk factors to create a risk-prediction tool for 90-day VTE in surgical patients. We also validated the predictive capacity of this risk model in a separate, independent dataset of surgical patients.

Materials and Methods

This study was part of a larger, statewide, observational, quality-improvement initiative. No care interventions were mandated. Thus, signed patient consent was waived. Analyses of deidentified Michigan Surgical Quality Collaborative (MSQC) data were approved by the University of Michigan institutional review board (HUM0025951).

The MSQC is a partnership among 52 Michigan hospitals, Blue Cross Blue Shield of Michigan, and the Blue Care Network. The MSQC methodology has been described previously.[17,18]

This project was limited to inpatient, nonemergent surgical cases (Table 1). The VTE data collection tool was affixed to the virtual workstation at 10 MSQC sites and was launched automatically when inclusion criteria were satisfied. Exclusion criteria included age < 18 years and admission for palliative care. Patients with recently diagnosed VTE for which they were actively receiving anticoagulation treatment were also excluded.

Data acquisition took place between March 2010 and October 2012. At the time of the project, the MSQC used the American College of Surgeons' National Surgical Quality Improvement Program platform to standardize data collection, using rigorous definitions for risk factors and outcomes. Thus, data from all MSQC sites underwent regular external audits to ensure data fidelity.[17] Data acquisition was performed by formally trained case reviewers. Excellent interrater reliability, with > 98.5% variable agreement during audits, has been shown previously.[17] Reviewers were required to make patient contact at 90 days via phone call or letter or to conduct a thorough review of medical records to identify postoperative complications diagnosed or managed at other institutions. Patients who lacked a 90-day follow-up were not included in the final database provided to the authors. Consequently, demographic data were not available for patients who lacked a 90-day follow-up.

Independent variables (Table 2) were defined rigorously. Definitions are summarized in e-Appendix 1. The primary outcome was 90-day, non-CVC-associated VTE, including patients with either DVT or PE. Upper-extremity DVT included clots in the jugular, subclavian, axillary, or brachial veins. Lower-extremity DVT included clots in the vena cava, femoral, tibial, or popliteal veins. Visceral DVT (eg, portal or mesenteric vein) or cerebral sinus thrombosis were not included in the primary outcome. PE included clots in the pulmonary vasculature. All VTE events were diagnosed using an objective imaging study. To avoid confounding in the final regression model, patients with CVC-associated DVT were considered to have only DVT if DVT was present at another anatomic site without a CVC. Similarly, PEs in the setting of isolated CVC-associated DVT were not considered PE events.

Statistical Analysis

Data analysis was performed using the Stata11 statistical package (StataCorp LP), and descriptive statistics on DVT, PE, and VTE incidence were generated. Bivariate statistics examined the

Table 1—*Derivation Cohort Categorized by Primary Procedure Type*

CPT Range of Primary Procedure	Type of Operation by Organ System or Area of Body	Total Patients (N = 6,768), No. (%)	Patients with DVT/PE (n = 95), No. (% Incidence Within the CPT Group)
10000-19999	Integument	455 (6.7)	2 (0.4)
20000-29999	Musculoskeletal	301 (4.5)	4 (1.3)
30000-33999	Respiratory and cardiovascular	110 (1.6)	2 (1.8)
34000-37799	Arteries and veins	1,391 (20.6)	9 (0.6)
38000-39999	Hemic and lymphatic system, mediastinum, and diaphragm	70 (1.0)	2 (2.9)
40000-43499 and 69500-69650	Head and neck, esophagus	70 (1.0)	1 (1.4)
43500-43999	Foregut (stomach, including gastric bypass procedure)	775 (11.5)	11 (1.4)
44000-46999	Hindgut (small bowel, large bowel, rectum, and anus)	1,988 (29.4)	40 (2.0)
47000-48999	Liver, biliary system, and pancreas	733 (10.8)	11 (1.5)
49000-49490	Miscellaneous peritoneal procedures	123 (1.8)	3 (2.4)
49491-49999	Herniorrhaphy	467 (6.9)	6 (1.3)
50000-53999	Urinary system	16 (0.2)	0
54000-59999	Genital system (male or female)	99 (1.5)	2 (2.0)
60000-60999	Endocrine	111 (1.6)	2 (1.8)
61000-64999	Nervous system structures	59 (0.9)	0

CPT = Current Procedural Terminology; PE = pulmonary embolus.